Introduction to NIF

Potential applicants to the Discovery Science call for proposals

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Outline

- Laser capability
- Target fabrication
- Target diagnostics
- Scheduling constraints

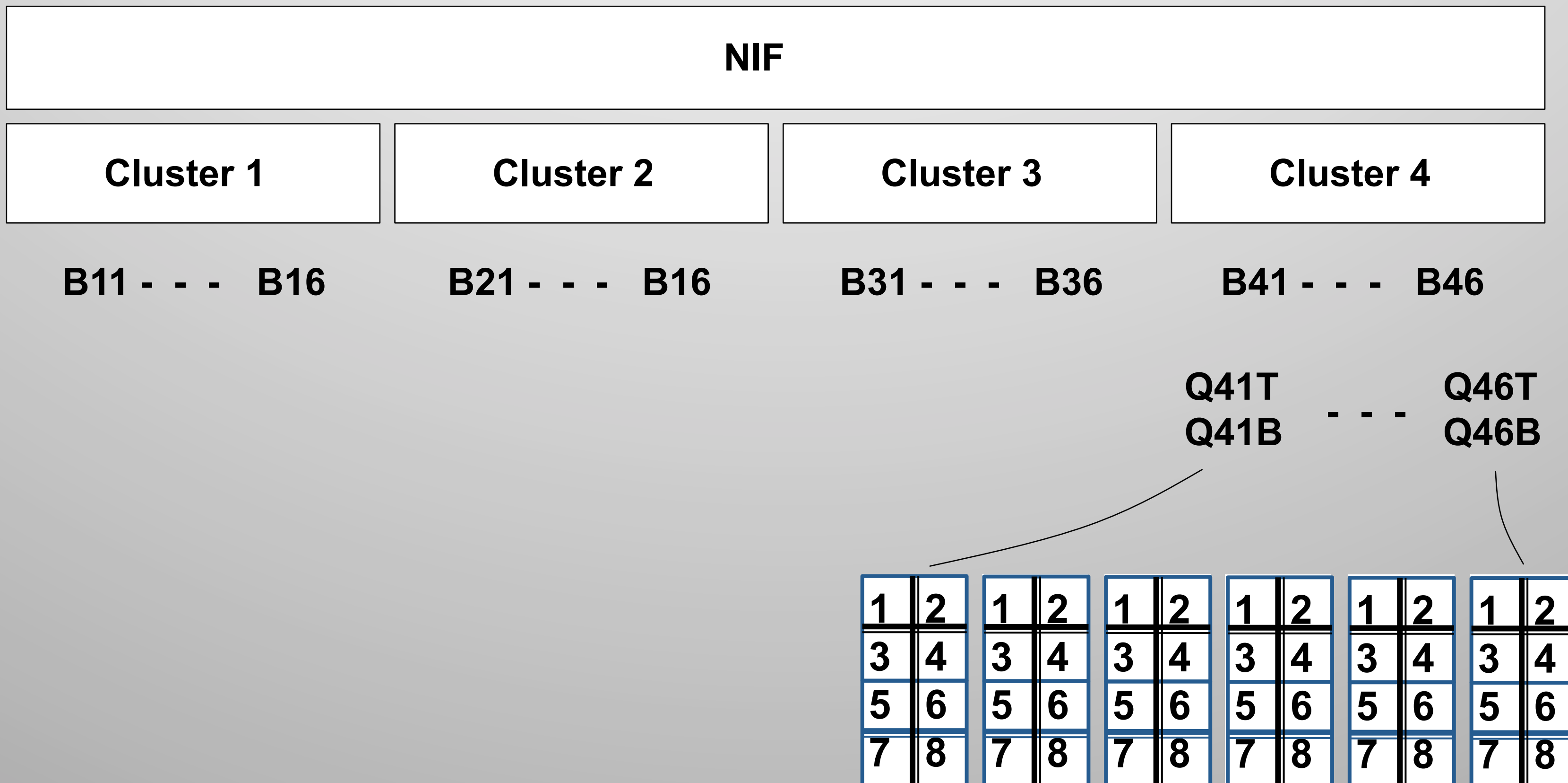
NIF is the world’s largest, highest-energy, highest-power laser: 1.86MJ — 523TW

Laser performance

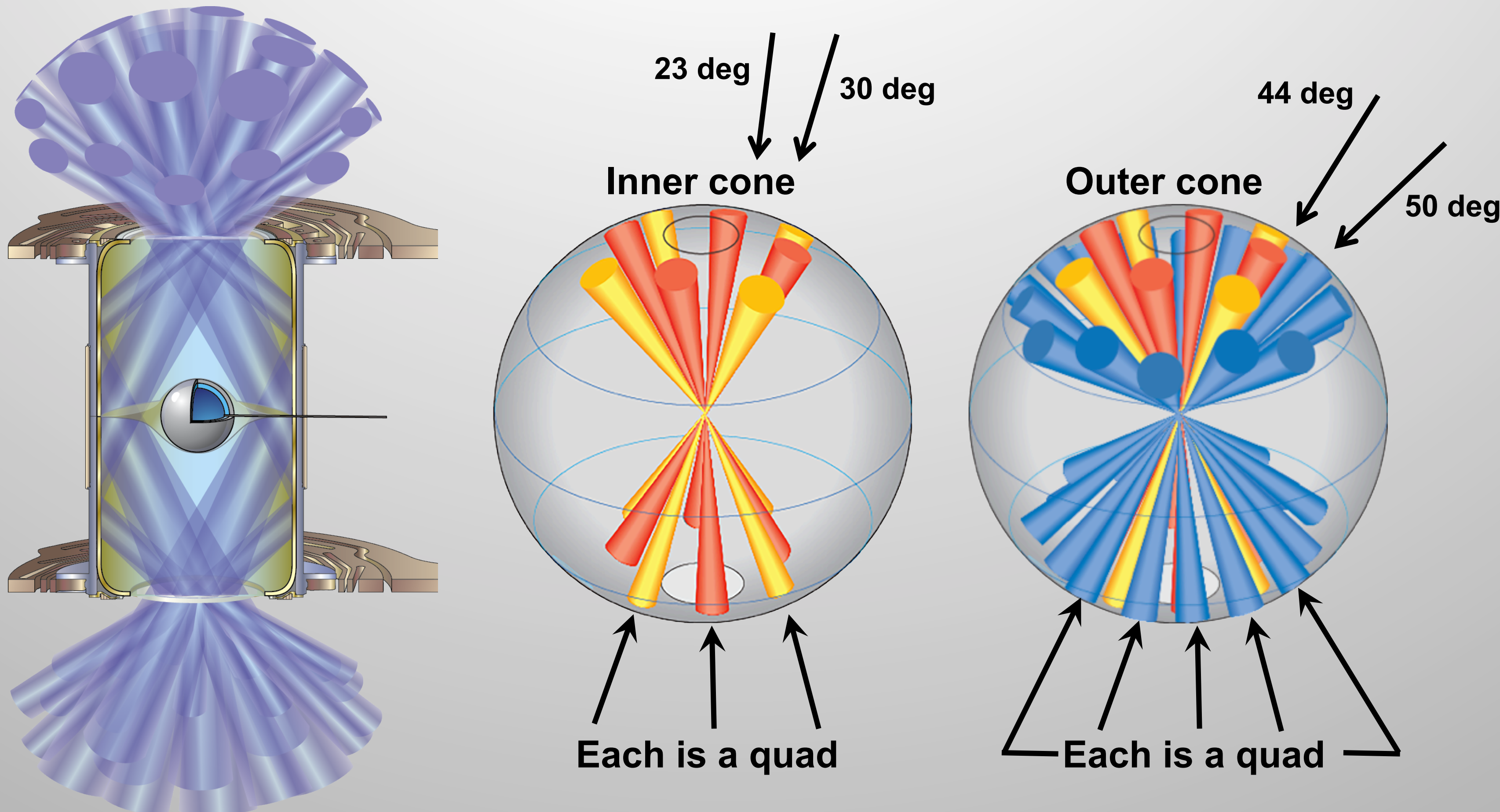
- NIF is a 192 beam laser designed to reliably deliver high power and energy to target to enable precision experiments
- Operation of the laser incorporates a living model of individual beam performance that is calibrated and adjusted to predict pulse shape delivery on individual shots to meet power balance and accuracy requirements
- Expert groups maintain reliable operation of the laser through review, planning and tracking of experiment impacts (machine safety) and performance
- NIF has a strategy of optics inspection and maintenance that allows it to operate “above the damage threshold” in a sustainable manner
- Operating below the damage threshold allows for more routine operation with a rapid shot cycle

Configuration

- NIF beams are grouped as clusters, bundles, quads, and beams
- Pulse shape, and timing are per quad, but timing with bundle limitations
- Energy is per beam, but with bundle limitations
- Pointing is per beam



The beams are grouped in inner and outer cones distinguished by polar angle



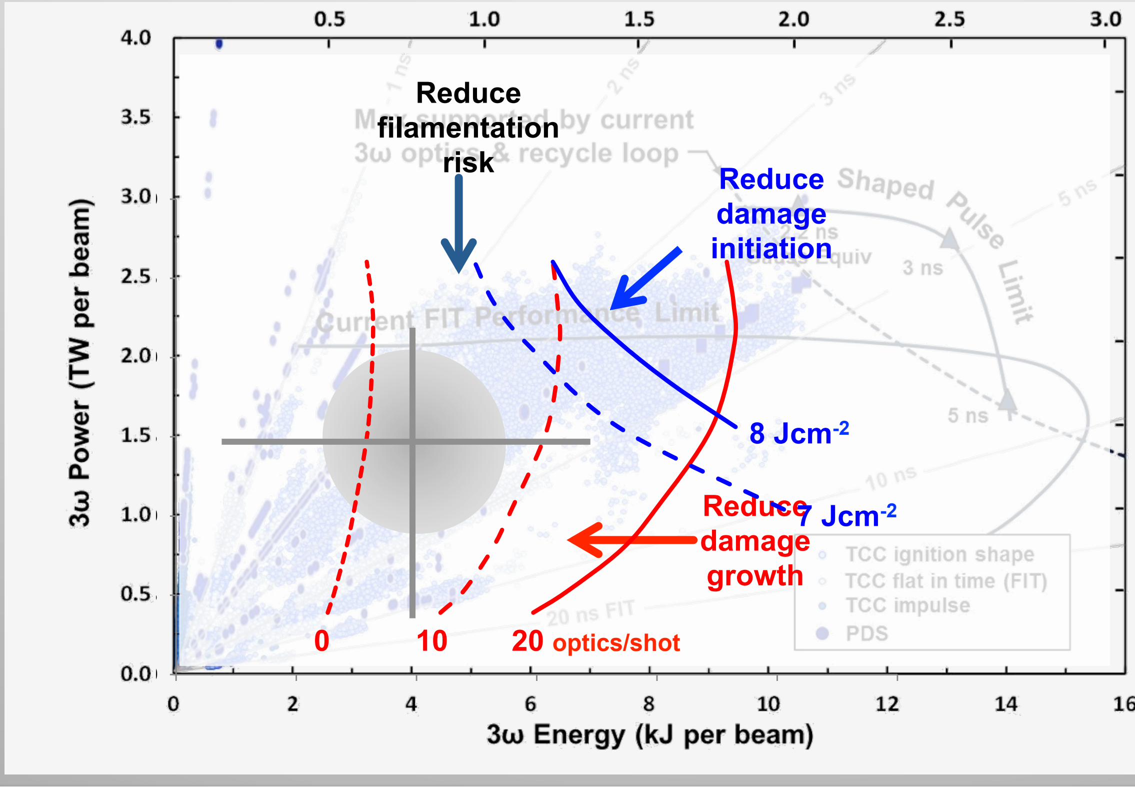
Groups of 4 beams (Quads) share some hardware and pulse shape capability → NIF is essentially 48 Quads each with 4 Beams

Pulse shape and energy

- Pulse shape
  - 88 ps impulse
  - >600 ps shaped pulses
    - 30 ns maximum pulse width
    - 100 ps rise at the beginning/end of the pulse, 600 ps transitions internal to the pulse shape
- Pulse timing
  - Flexible pulse delays – but depend on energetics and power
  - Generally up to 30 ns delay available
  - Longer delays are special request and require more setup time and review
  - Timing is limited between quads in the same bundle
- Energy
  - There are power and energy limits associated with beam filamentation, and optics damage initiation and growth
  - 88 ps is limited to 56 J/beam
  - 3.3 ns square can be used at <4 kJ/beam
  - Shaped ignition pulses can be run at ~4 kJ/beam (800 kJ NIF) with minimal impact

The NIF laser performance limits are driven by optics damage and non-linear effects

- NIF is capable of 1.8 MJ operation with a high-contrast shaped pulse
- Operation at this level exceeds the initiation and damage threshold for the NIF final optics (effectively uses up optics)
- Operation in a moderate power/energy space reduces the impact and allows for more shots

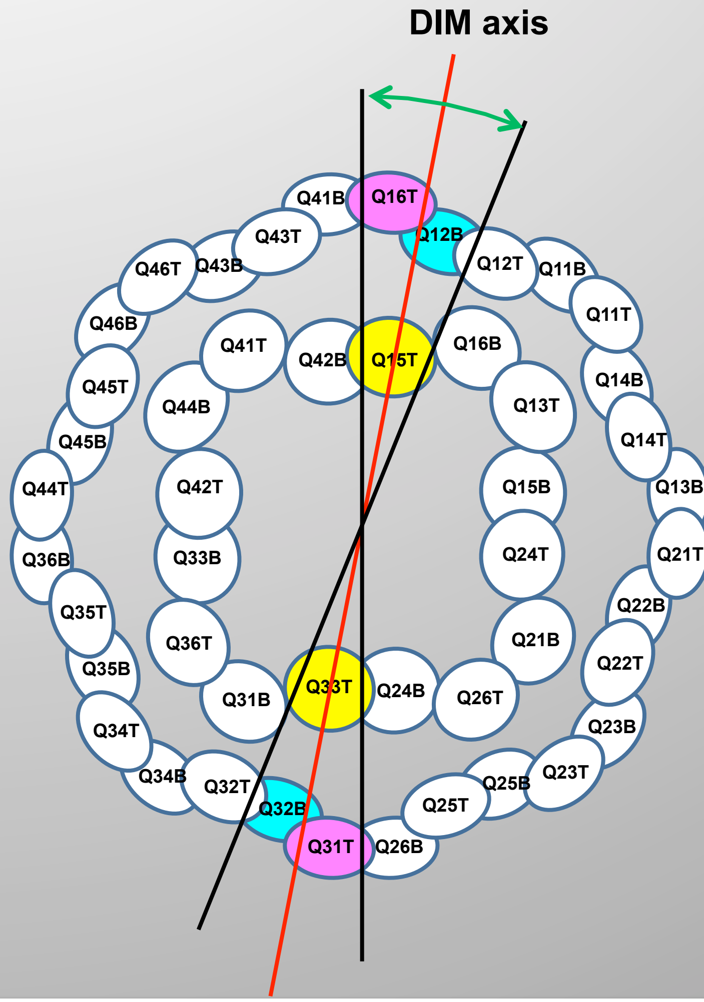


Representative plot based on flat-in-time pulses

Beam pointing

- Beam pointing is currently limited to +/- 5 mm left/right and +/- 30 mm up/down wrt TCC (beam perspective)
  - There are individual limits per beamline

- Beam pointing limits affect the achievable standoff for backlighters
- Example: quads available for backlighting along the 90-78 DIM axis:
  - 6 quads can reach 34 mm offset



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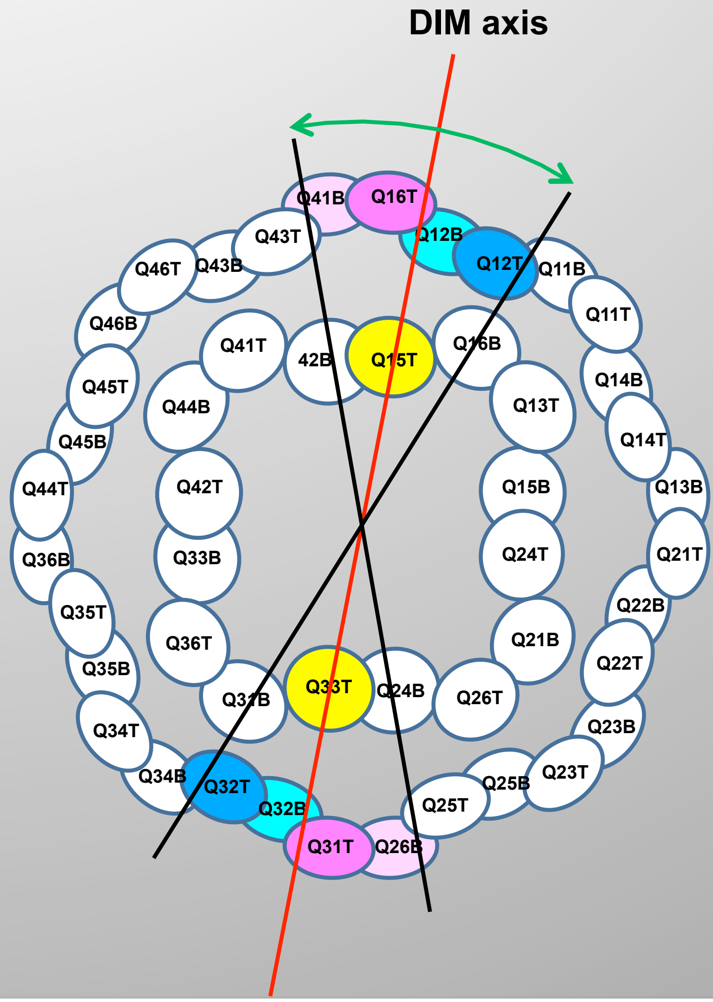
  - 10 quads can reach 14.9 mm offset



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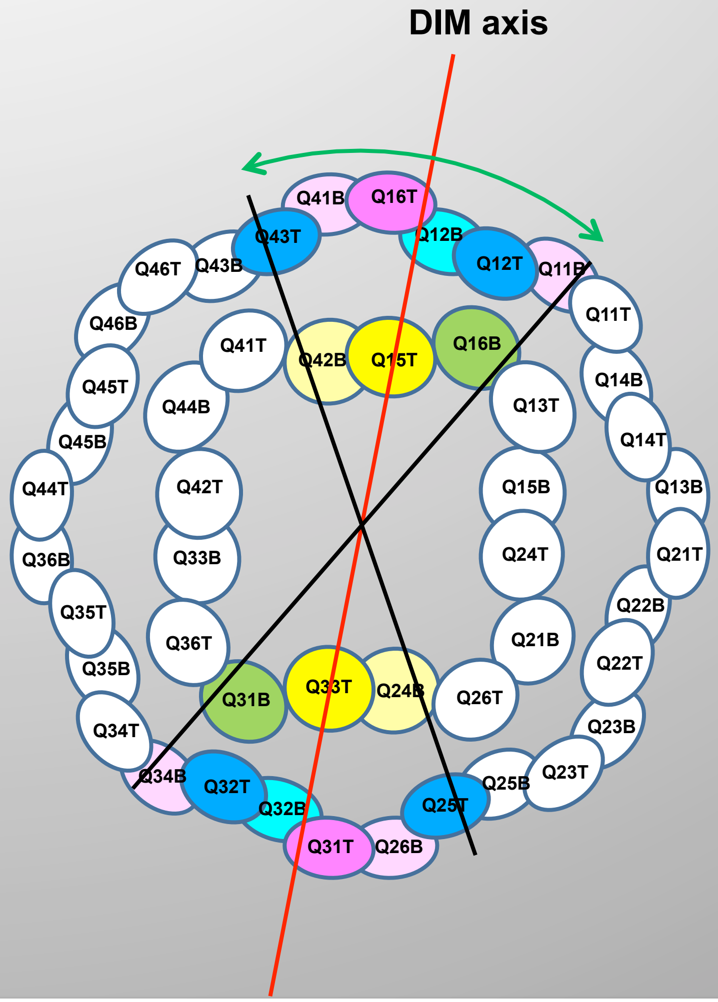

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- Example: quads available for backlighting along the 90-78 DIM axis:
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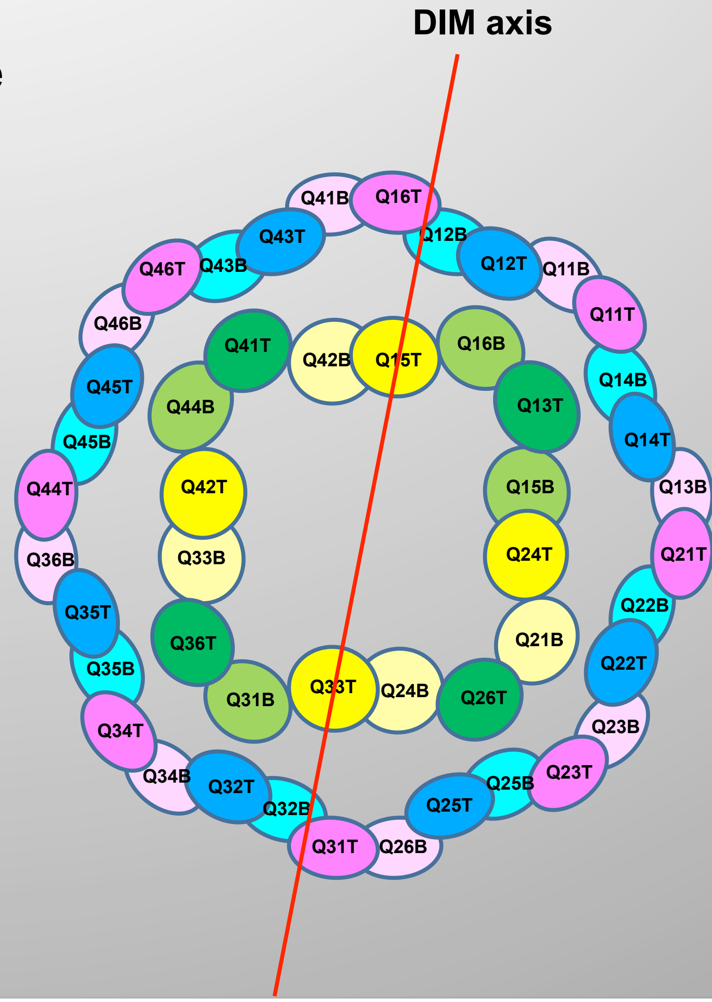
  - 10 quads can reach 14.9 mm offset
  - 18 quads can reach 9.7 mm offset
  - 48 quads can reach 5 mm offset



ARC capability is currently being commissioned

- 1 NIF quad (35T) may be used in a short pulse mode (ARC)
  - 2 beams are each split into 2 beamlets

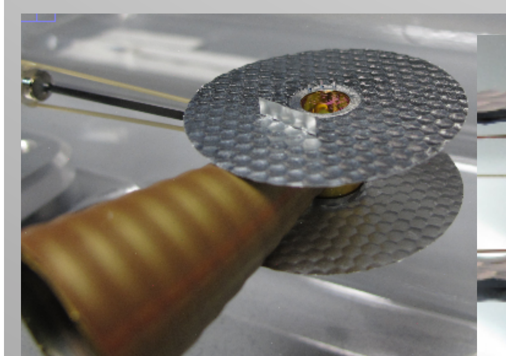
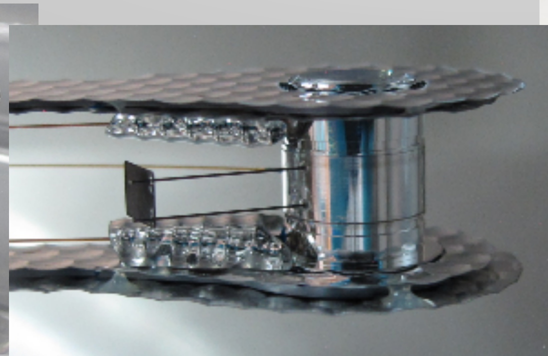
- 30 ps impulse, expected capability of 1000-1200 J/beamlet
  - Damage threshold issues not yet understood, useful manageable energy range is TBD

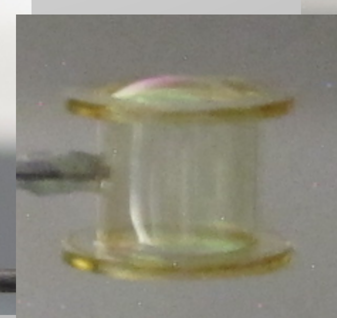
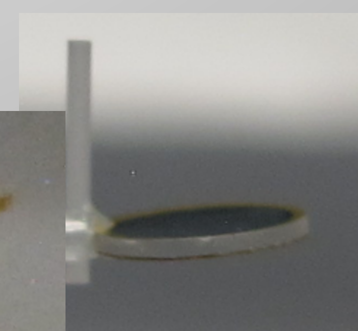
- Relative beamlet pointing and timing are limited
  - Co-pointing beamlets from the same beamline is ok over the nominal NIF pointing volume

- ARC is being first commissioned for program use with wire backlighters at approximately 6 to 30 mm from TCC

Targets

- Target fabrication support is provided by the LLNL target fab team
  - Target requests in successful proposals will be evaluated in light of current fabrication capability and budget
- Capabilities:
  - Hohlraum/halfraum
  - Direct drive foils
  - Gas pipes
  - Shock tube
- Targets based on existing experimental platforms will streamline the review process and subsequent fabrication

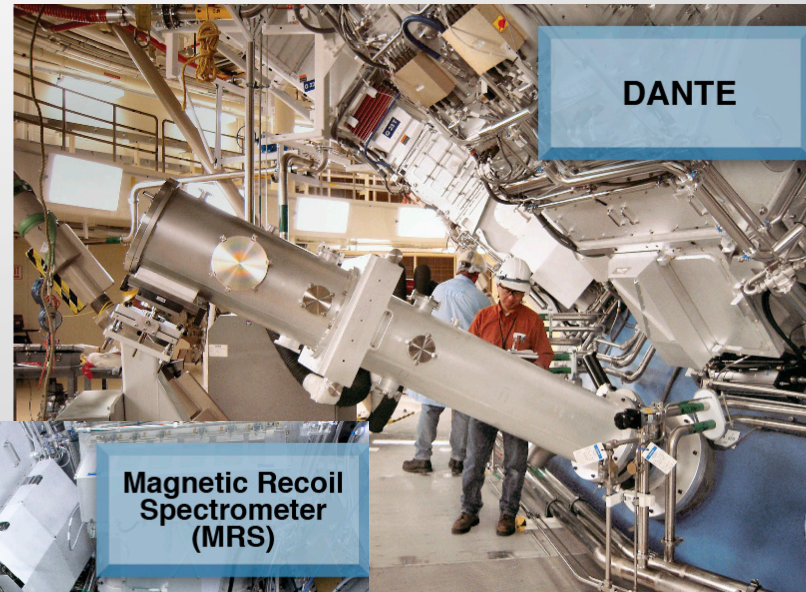



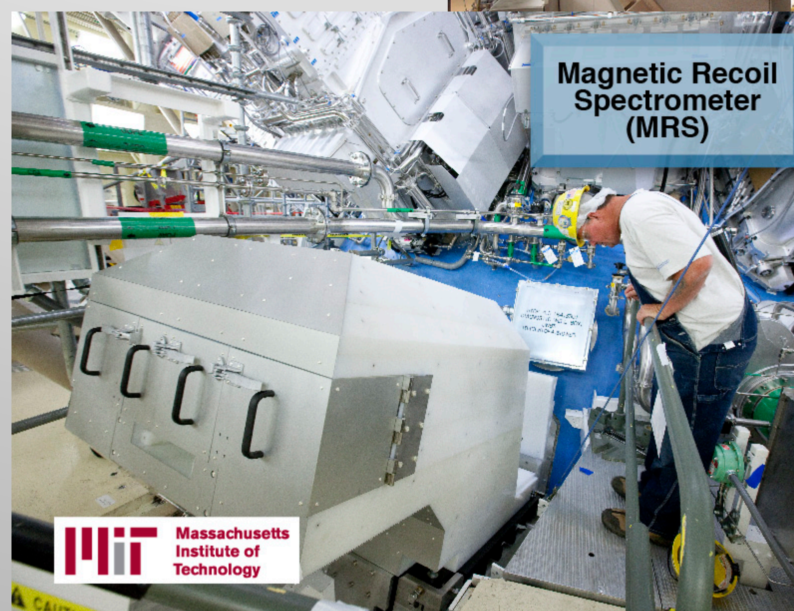
Target chamber

- The NIF chamber is 10 m in diameter, maintained at high vacuum
- 3 DIM lines of sight for insertable diagnostic access to view the target
- Target, diagnostic snouts, and filters are exchanged or refurbished on each shot
- The number of diagnostic transactions between experiments impacts the overall shot cycle duration

Diagnostics

- X-ray
  - Fixed – Dante, FFLEX, SXI, DIXI, SPIDER
  - DIM-based – streaked and gated imagers with pinhole and spectrometer snouts
  - X-ray bang time
- Optical
  - FABS/NBI
  - VISAR
- Nuclear
  - Yield
  - NToF
  - MRS
  - Neutron imaging
  - Neutron bang time





Examples

- Implosion core imaging
  - 12X with 0.25 mm field of view (before overlapping images)
  - 4-7.8X imaging with 1-1.5 mm field of view for in-flight imaging
  - 2X with 3 mm field of view for early-time capsule drive symmetry

- Backlighting
  - 1-4X imaging with larger field of view

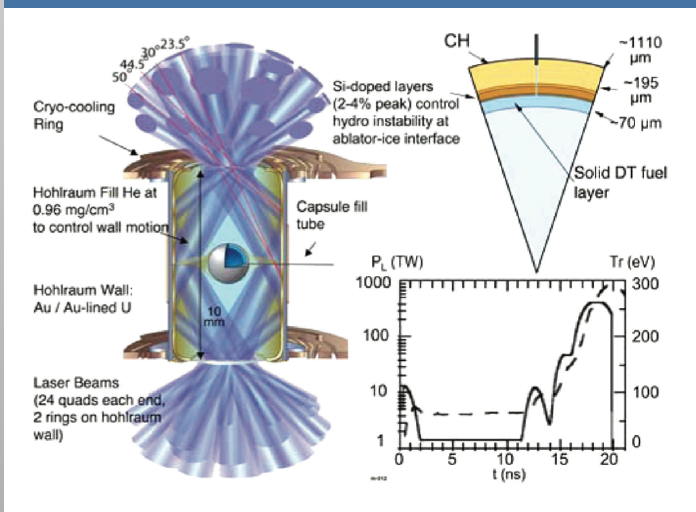
- Spectroscopy
  - Wavelength coverage capability at 2-18 keV
  - Energy resolution of E/dE ~ 100-300

Ignition implosion platform

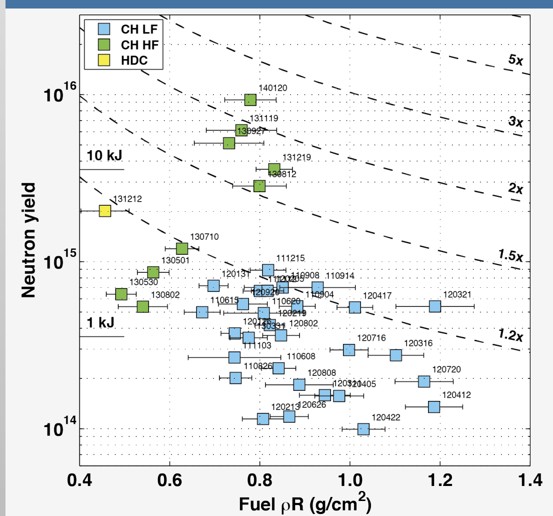
https://lasers.llnl.gov/content/assets/docs/for-users/platforms_indirect_direct_drive.pdf

- Layered DT ignition capsules
  - Contain solid cryogenic DT fuel layers
  - Designed to ignite and burn producing ~10-20 MJ of energy

Schematic of NIF ignition target, capsule and a typical laser pulse (solid line) and resulting simulated X-ray drive (dashed line)



Total neutron yield vs. fuel ρR for all cryogenic layered implosions on the NIF



Current conditions achieved

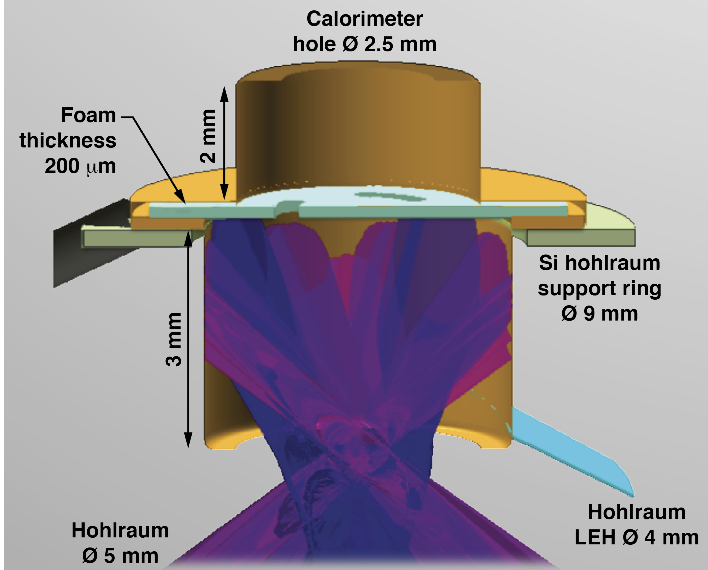
- High Y_n ~ 10^{14}-10^{16}
- Rapid burn ~ 50-100 ps
- Burn avg temp ~ 5 keV
- Burn avg density ~150-300 g/cm^3

Half-hohlraums

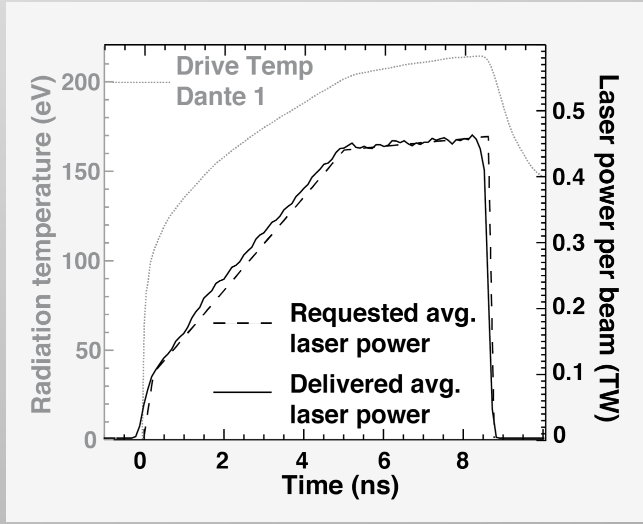
- Half-hohlraum provides capability for radiation driven samples placed on the axis for hydrodynamics and radiation flow experiments

https://lasers.llnl.gov/content/assets/docs/for-users/platforms_half_hohlraum.pdf

- Subsonic Radiation Transport
  - Subsonic Radiation Transport experiments study the evolution of an "N-wave" density structure in slots cut into a Ta_2O_5 aerogel



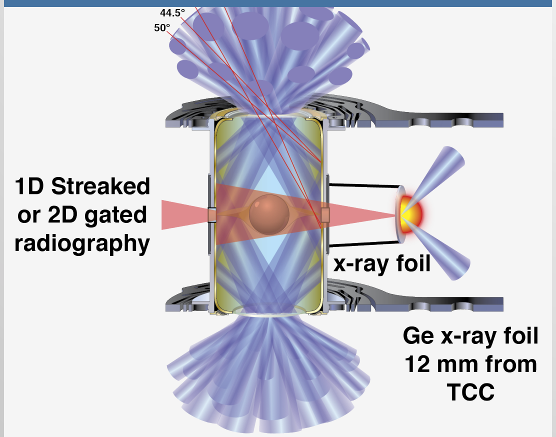
- A large 4.0 mm diameter half-hohlraum, driven by 80 lower quads, creates a power-law-in-time x-ray drive over 9.0-12.0 ns with a 200-240 eV peak temperature
- The x-ray drive launches a shock followed by a subsonic Marshak wave in the aeroge
- Slots machined in the aerogel evolve into an "N-wave" density profile



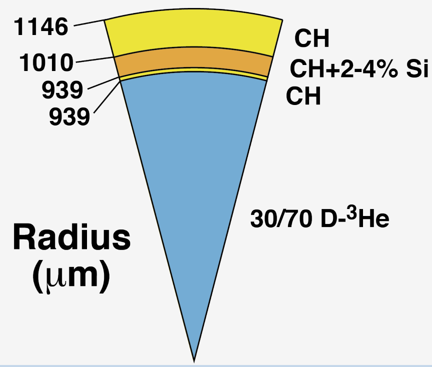
Radiography platforms

https://lasers.llnl.gov/content/assets/docs/for-users/platforms_horizontal_vertical_axis_radiography.pdf

Experimental setup

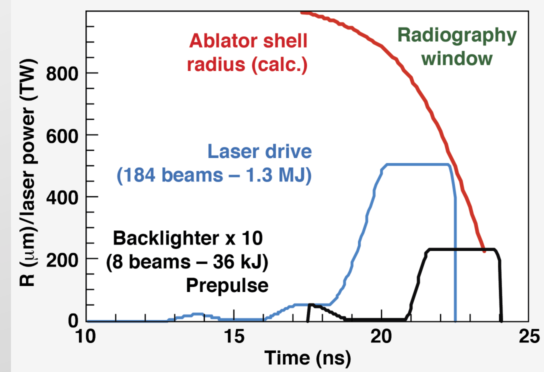


Symcap target

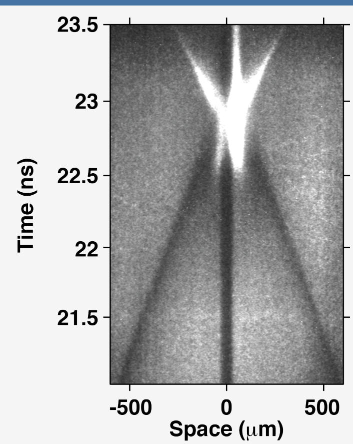


Cross section of spherical target

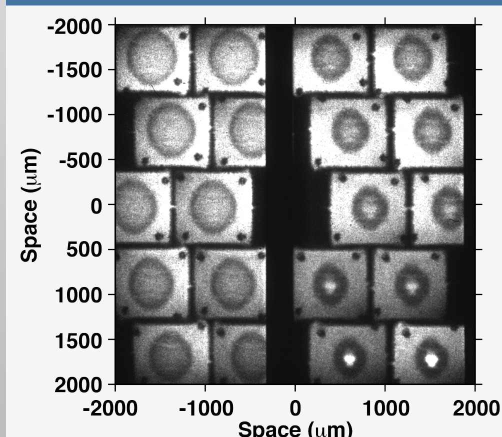
Laser pulse shape



1D equatorial radiograph



2D equatorial radiograph

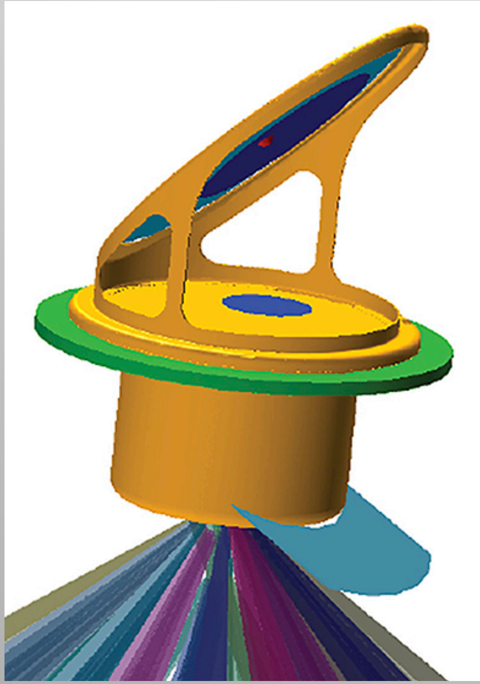


Shock timing and equation of state

- Example shock timing measurement from a planar foil driven by a half hohlraum x-ray drive

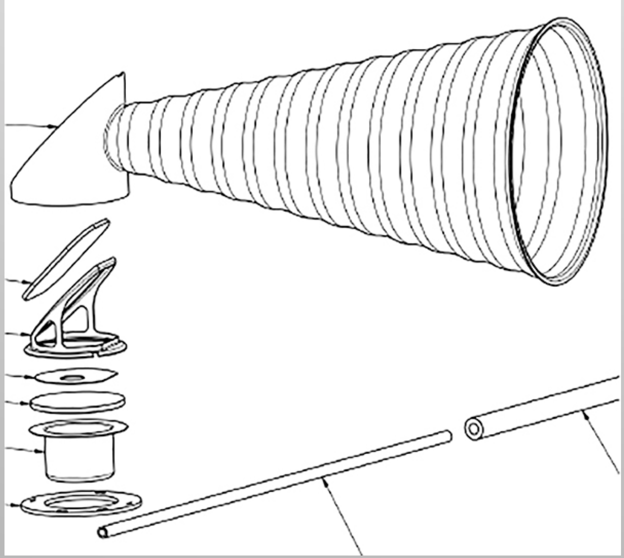
https://lasers.llnl.gov/content/assets/docs/for-users/platforms_shock_timing_eos.pdf

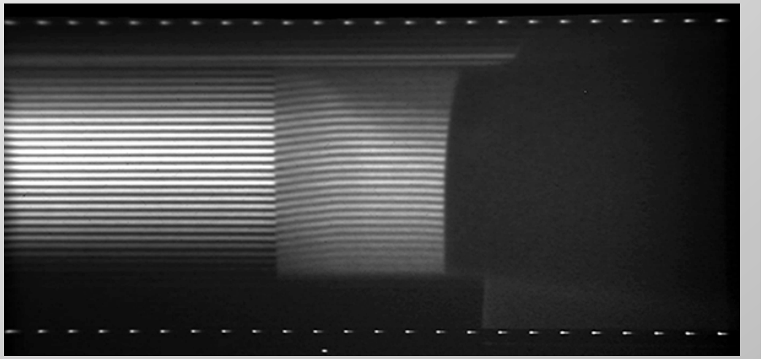
- VISAR view of the target is achieved with a fold mirror mounted on the target



- Warm target
- Vacuum hohlraum

- Mirror requires a shield cone to protect it from scattered and unconverted light



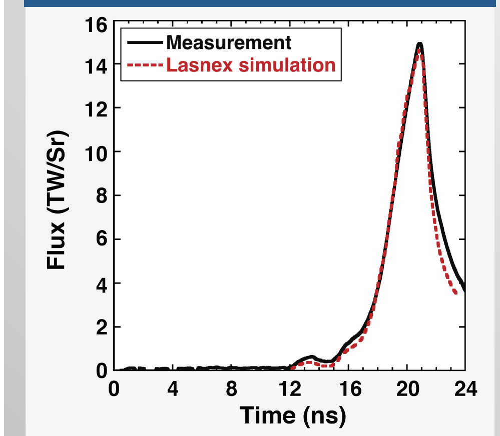


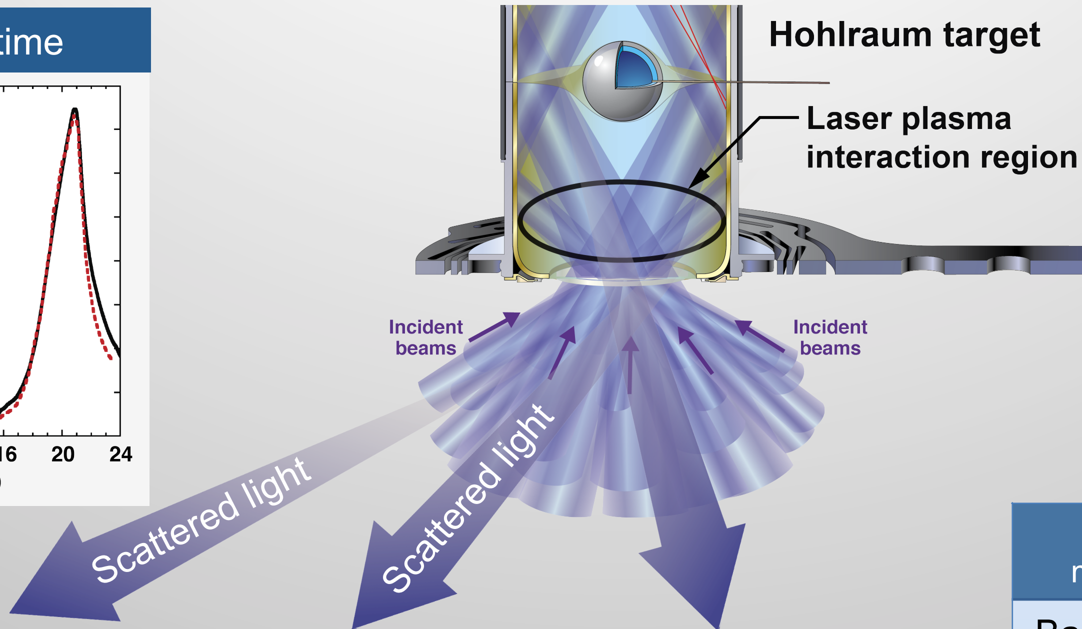
- Compatible with additional x-ray diagnostics
  - Backlit radiography
  - X-ray Thomson scattering

Laser plasma interactions

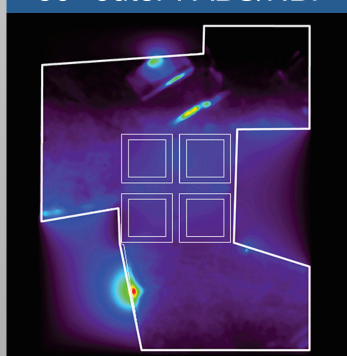
https://lasers.llnl.gov/content/assets/docs/for-users/platforms_lpi.pdf

Dante flux vs time

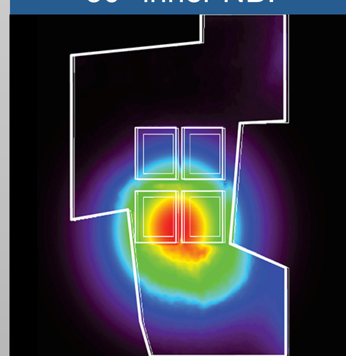




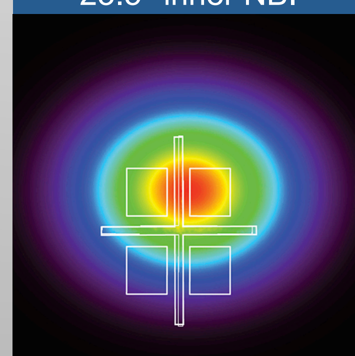
50° outer FABS/NBI



30° inner NBI



23.5° inner NBI



Optical scatter measurement capabilities	
Backscatter level	Required accuracy
25%	15%
10%	20%
2%	50%

- 200 ps time resolution
- 5 nm SRS: 0.3 Å SBS

Scheduling

- NIF schedule process
  - Identify a ‘train schedule’ based on common diagnostic configurations
  - Assign campaigns and shots into the schedule based on the assigned configuration
- Successful proposals will be awarded time
- Allocation of time may be effectively used by matching existing configurations and minimizing CPP transactions and red-line laser performance requirements
  - Typical shot cycle today is 8-12 hrs
- Requirements for new capabilities drives scheduling
  - There is a separate process to propose new major capabilities
  - Engineering to support new capability must be coordinated with facility scheduling
- There is a minimum set of information to assess and schedule experiments
  - Energy/ peak power/ lines of sight/ cryo vs warm/ CPPs/ diagnostic selection

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